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Professional Development System Design for Grades 6-12 Technology, Engineering, and Design Educators

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Dr. DeLuca has taught middle school, high school, undergraduate and graduate level technology education in his 27 years as a teacher and researcher. He has extensive research and curriculum development experience in STEM disciplines. His research includes the study of thinking processes, teaching methods, and activities that improve technological problem-solving performance and creativity. He has expertise in developing technology education curriculum that integrates science, technology, engineering and mathematics (STEM) concepts. Currently, Dr. DeLuca's research includes projects to develop curricula to teach STEM concepts associated with renewable energy technologies by providing a living laboratory of performance data from numerous renewable energy systems. The overarching goal of the project is to develop middle school, high school and undergraduate students' higher-order thinking skills in the context of a data-rich learning environment. In addition, he is researching and developing professional development systems for technology and engineering education teachers.

Dr. Laura Bottomley, North Carolina State University

Dr. Laura Bottomley received a B.S. in Electrical Engineering in 1984 and an M.S. in Electrical Engineering in 1985 from Virginia Tech. She received her Ph D. in Electrical and Computer Engineering from North Carolina State University in 1992. Dr. Bottomley worked at AT&T Bell Laboratories as a member of technical staff in Transmission Systems from 1985 to 1987, during which time she worked in ISDN standards, including representing Bell Labs on an ANSI standards committee for physical layer ISDN standards. She received an Exceptional Contribution Award for her work during this time. After receiving her Ph D., Dr. Bottomley worked as a faculty member at Duke University and consulted with a number of companies, such as Lockheed Martin, IBM, and Ericsson. In 1997 she became a faculty member at NC State University and became the Director of Women in Engineering and K-12 Outreach. She has taught classes at the university from the freshman level to the graduate level, and outside the university from the kindergarten level to the high school level. She is currently teaching courses in engineering, electrical engineering and elementary education. Dr. Bottomley has authored or co-authored more than 40 technical papers, including papers in such diverse journals as the IEEE Industry Applications Magazine and the Hungarian Journal of Telecommunications. She received the President's Award for Excellence in Mathematics, Science, and Engineering Mentoring program award in 1999 and individual award in 2007. She was recognized by the IEEE with an EAB Meritorious Achievement Award in Informal Education in 2009 and by the YWCA with an appointment to the Academy of Women for Science and Technology in 2008. Her program received the WEPAN Outstanding Women in Engineering Program Award in 2009. In 2011 she was recognized as the Women of the Year by the Women's Transportation Seminar in the

Research Triangle and as the Tarheel of the Week. Her work was featured on the National Science Foundation Discoveries web site. She is a member of Sigma Xi, past chair of the K-12 and Precollege Division of the American Society of Engineering Educators and a Senior Member of the IEEE.

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Abstract

The Transforming Teaching through Implementing Inquiry (T^2I^2) research and development project, recently funded by the National Science Foundation, has developed a pilot version of its interactive, object-oriented, and networked cyber infrastructure for providing professional development for in-service grades 6-12 technology, engineering and design educators. The T^2I^2 system development has been guided using research-validated professional development practices along with state-of-the-art course/content management and collaboration software to increase engineering-design oriented instructional skills of teachers. T^2I^2 has completed the initial development phase of the full scale research and development project resulting in a professional development cyber infrastructure for technology, engineering and design educators – a dynamic, interactive and collaborative online system for improving the quality of teaching in engineering and design education classrooms. Through the use of techniques and protocols, such as Ajax, DHTM, CSS, XML and PHP, the T^2I^2 project team has constructed a system that provides: 1) the content knowledge needed to implement inquiry-based instruction, 2) data analysis tools to evaluate learning needs and monitor inquiry-based learning, and 3) running averages and variability so teachers can compare these measures against norms in order to manage, monitor and adjust the learning environment, and conduct personal self-assessment techniques. The system has also been designed to archive and permit access to teacher user data profiles such as metric indicated teacher behavior, competency-based quiz outcomes, access frequency, time on task, and attempts of a unit. This information is analyzed and reported to document competency attainment of the 16 in-service teachers and potential complications with the teachers achieving concepts conveyed. These system development processes, system features, and user results associated with teacher progression are reported and incorporated to provide for a data-informed architecture and professional development content examination.

Introduction

Deeply rooted professional development that is flexible but structured is a necessity in educational improvement and reform[1], and intensive, targeted and ongoing professional development is a foundational step. This professional development must focus on individual development, content-specific teaching skills and student learning outcomes[2]. Professional development providing content-specific teaching skills supports clear and concrete actions that lead to improvement in both teaching quality and student achievement[3]. Garet, Porter, Desimore, Birman and Yoon (2001) list six factors that have a significant positive effect on teachers' knowledge and skills, and change in classroom practice[4]. These factors include content knowledge, active learning, coherence, time span, duration and collective participation. The National Board for Professional Teaching Standards (2001) identifies four major areas where effective and accomplished teachers exhibit high levels of proficiency: creating conditions for productive learning; actions that directly advance student learning in the classroom; actions that help students transition to work and adult roles; actions that indirectly support student learning through professional development and outreach initiatives[5]. Research shows that "teachers who receive rich and sustained professional development…geared toward higher-order thinking skills and concrete activities such as laboratory experiences, are more likely to engage in effective classroom practices"[6].

In the design and implementation of professional development services and activities, professional development providers must take advantage of the most current state-of-the-art cyber technologies if K-12 technology, engineering, and design educators are to be kept abreast of the latest developments in their fields. Unfortunately, technology, engineering and design education professional development resources related to instructional strategies, methodology, and standards-based learning are few and far between. The Transforming Teaching through Implementing Inquiry (T^2I^2) project utilizes a web-based architecture and interface to close this gap. The project is in the process of finalizing an environment for interactive professional development, information sharing, and collaboration.

T^2I^2 project

The T^2I^2 project is in the initial stages of delivering a research-based, interactive, object-oriented and networked cyber infrastructure for providing professional development to technology, engineering and design educators. At the time of this proceeding development, pilot testing had been underway for approximately three months. The T^2I^2 system is continually being developed using research-validated professional development practices along with state-of-the-art course/content management and collaboration software to increase engineering-design content knowledge and instructional skills of teachers. Upon completion of professional development training through T^2I^2, teachers will have been exposed to a representative portion of National Board Certification (NBC) requirements. NBC has many advantages such as expansion of teacher expertise and influence, and increased portability and salary potential. A focal emphasis is creating dynamic learning environments for students to improve competency in engineering-design content through enhanced teacher practices and knowledge. In addition to advancing student subject knowledge, creating dynamic learning environments includes using validated assessment techniques to understand student needs, constructing mutual and supportive classroom structures centered on inquiry, and creating cultures where diversity, impartiality and equality are taught and exhibited. The project aims to improve the quality of 6-12 technology, engineering and design educators' teaching of standards-based engineering-design content through the implementation of a cyber infrastructure that incorporates innovative, research-based applications for high quality professional development. Research and development (R&D) activities assist in gauging the effectiveness of the proposed framework for professional development, determining with whom the approach works and under what circumstances.

The Learning Objects – Design

The granularity of learning objects (LOs) allow components to be configured for different venues. For example, objects can be configured as units for undergraduate methods classes, a three-day workshop for lateral entry teachers or a three-hour workshop for in-service teachers. Delivering learning objects in an online network allow for customization and collaboration as teachers grow in a network community. Learning objects are especially suitable for the guided, individualized instruction that can be provided over the T2I2 web-based system (see Figure 1). Project LOs are currently categorized into four units for the purposes of implementation for in-service technology, engineering, and design educators: 1) Assessment of Student Learning, 2) Demonstration Lessons, 3) Fostering Teamwork, and 4) Documented Accomplishments. Each of these units are in alignment with the National Board for Professional Teaching Standards (NBPTS). In addition to this object-oriented design, the team has incorporated state-of-the-art cyber technologies to provide an interactive environment that can dynamically adjust professional development needs. Today's interactive and collaborative Web 2.0 technologies, first popularized in social websites, have spilled over into government, economic and educational sectors. The evolving infrastructure of these technologies has moved browsing to a participatory networked platform.

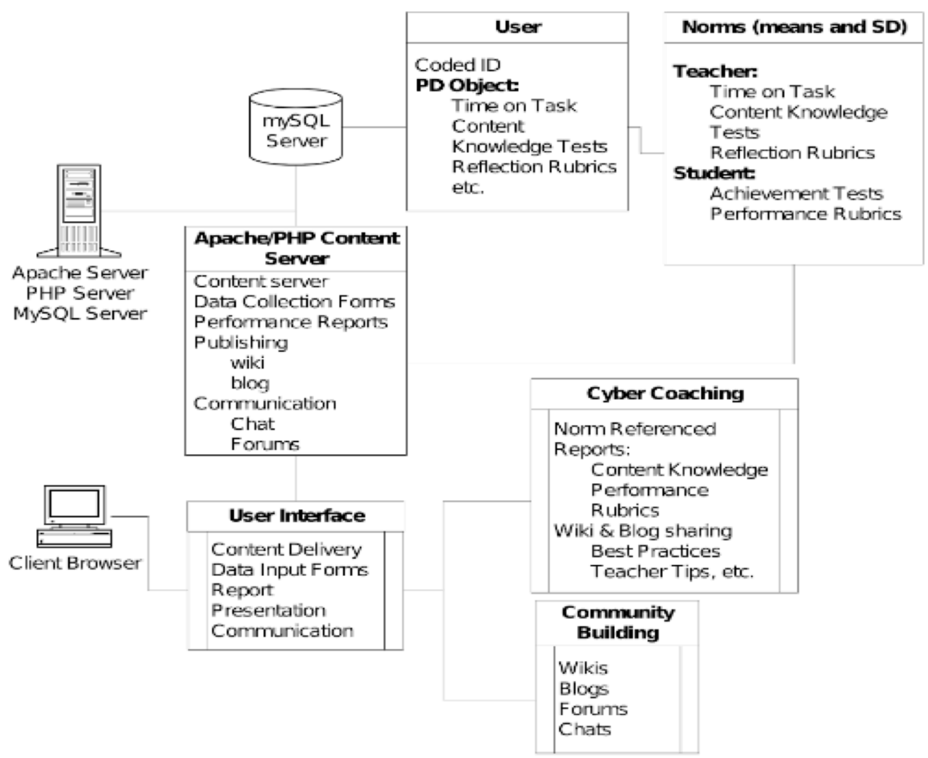

Figure 1. T2I2 system architecture

The architecture and content of the professional development materials (LOs) developed by the team were driven by two types of standards – professional teaching standards and curriculum content standards. The professional teaching standards were those of the NBPTS. The curriculum content standards were derived from those of K-12 national science, mathematics, and technology/engineering. First, NBPTS and its relationship with the T^2I^2 learning objects will be outlined.

The NBPTS was founded in 1987. Its mission "is to advance the quality of teaching and learning by maintaining high and rigorous standards for what accomplished teachers should know and be able to do, providing a national voluntary system certifying teachers who meet these standards, and advocating related educational reforms to integrate National Board Certification in American education and to capitalize on the expertise of National Board Certified Teachers." The NBPTS "seeks to identify and recognize teachers (primarily Pre K – 12) who effectively enhance student learning and demonstrate the high level of knowledge, skills, abilities and commitments reflected in the following five core propositions"[5]. First, teachers are committed to students and their learning. Second, teachers know the subjects they teach and how to teach those subjects to students. Third, teachers are responsible for managing and monitoring student learning. Fourth, teachers think systematically about their practice and learn from experience. Fifth, teachers are members of learning communities.

The NBPTS certification process is rigorous and detailed taking place during one academic year of teaching. During a given school year (of the teacher's choosing) the teacher submits four portfolio entries and near the end of the school year, takes a written examination comprised of six exercises at a NBPTS assessment center. If the teacher's portfolio entries and examination meet the board's standards, the teacher is granted NBPTS certification. The NBPTS program certifies 24 teaching areas. Technology education is included under the Career and Technical Education (CTE) certification area. With regards to CTE teachers, the National Board has identified thirteen standards (see Table 1) that all accomplished CTE teachers must demonstrate a deep understanding of and accomplished practice in (left column). After much deliberated analysis and evaluation, the leadership team developed seventeen learning objects (see Table 1) that would assist teachers in developing the required NBTS understandings and skills (right column).

Table 1. Display of NBPTS and T2I2 learning objects

13 NBPT Standards	17 T^2I^2 Project Learning Objects
Knowledge of students	Action Research
Knowledge of subject matter	Adapting Instruction
Learning environments	Best-practices
Diversity	Classroom Quality
Advancing knowledge of Career and Technical subject matter	Data Analysis
	Designing Standards-based STEM Curriculum
Assessment	Enhancing Classroom Creativity
Workplace readiness	Formative Evaluation Techniques
Managing and balancing multiple roles	Implementing Learning Activities
(Students') Social development	Initial Student Evaluation
Reflective practice	Lab and Class Management
Collaborative partnerships	Multiculturalism in the Classroom
Contributions to education profession	Professional Organizations
Family and community partnerships	School and Community
	STEM Curricula
	Student Organizations
	Working with Special Populations

STEM Curricula Content Standards

All teaching is done within a context, whether it is engineering, science, technology, mathematics or music. Not only must an accomplished teacher have strong pedagogical skills, he or she must also have a deep understanding of the content and skills of their own subject area and a firm grasp of the common core subject areas upon which their subject area rests. The NBTS CTE Standard 2 reads "Accomplished career and technical educators command a core body of knowledge about the world of work and the skill/processes that cut across industries, industry-specific knowledge, and a base of general academic knowledge". The T^2I^2 Project Team decided to use nationally recognized K-12 curriculum content standards in science education, mathematics education, and technology/engineering education.

Specifically five national STEM curriculum standards projects were identified: SfTL[7] (Standards for Technological Literacy; SfAA[8] (Science for All Americans); NSES[9] (National Science Education Standards); *Next Generation Science Standards* based on the *Framework for K-12 Science Education*[10] and PSfSM (Principles and Standards for

School Mathematics)[11]. Teachers, teacher educators, and business and industry stakeholders developed all five curricula standards. The development of the technology standards also included engineers, and scientists.

The incorporation of the STEM curriculum content standards was accomplished in several ways. First, one learning object, titled "Designing Standards-based STEM Curriculum" was dedicated exclusively to developing a basic understanding of the six curriculum standards mentioned above. Secondly, all examples of the application of the various pedagogical understandings and applications used concepts and principles from these areas. Next, all curriculum writers were from STEM areas and finally, all teacher and student activities and the accompanying assessments were standards-based.

In summary, the development of the learning objects demanded that collectively they would reflect the understandings and skills required by the NBPTS as well as reflect necessary STEM and ELA curriculum content standards. Additional design criteria included that while each LO would have a strong theoretical research base, each would be practical and capable of being immediately applied in the classroom. Each of the seventeen LOs followed a specific format. The LOs start with an overview that contains a short description of the LO and the specific CTE NBPT Standards addressed within the LO. Next each LO has a description. In the description there are a specific "learning objectives" for the LO. For example, upon completion of this learning object you will be able to: "Respond to the results of formative assessment and modify your instruction accordingly". After the description, the next section is impact on learning. Included in the impact on learning is why the LO is meaningful to classroom practice, explicit examples of practical application, and the essential concepts being addressed. The next section in the LOs, procedures in the classroom, provides a step-by-step example of the application of the concepts covered as well as an example using standards-based content. Then, rubrics for the teacher to use in assessing whether or not he or she was successful in apply what was learned are provided in the determining success section. Finally, the LOs end with appendices that include site and on-line resources and references.

Pilot Site Teacher Selection and Implementation

As noted earlier, the project consisted of three major components: creation of high quality professional development materials for technology, engineering and design (TED) middle and high school teachers; a mechanism for delivering these materials; and a process that would serve as both a model and as a measure of the overall efficacy of the entire plan. The project's research and development design argued for the random selection of TED teachers from more than one state or locale. Therefore it was decided that states would be invited to participate, each state agreeing to do so would solicit participation from its population of middle and high school TED teachers and from the population of interested teachers, the project team would randomly select the project's pilot teachers. The following is a description of the evolution of the teacher selection process.
In time, four states agreed to participate - Virginia, North Carolina, Illinois, and Ohio. The project team worked directly with the state supervisors of Technology Education from the Departments of Education. Communication with the state supervisors began

early in the fall of 2011. The information included the project's overview and goals and most importantly, the role the supervisors were to play. This included, along with their role as advisors to the project team's leadership, the initial contact with their states' teachers. In early February, 2012 all the supervisors sent out a flyer that the project team had developed to their teachers via the Internet. The T^2I^2 flyer gave a brief description of the project and called for their participation. Interested teachers registered on-line filling out a web-based information survey. In states where the response was slow, the flyer was redistributed. By March, 191 teachers had registered through the electronic survey. While the numbers were robust, it was quickly found that many of the teachers were from areas other than TED. It is believed that part of the problem stemmed from the broad use of the word technology. Many teachers came from the areas of business education, some from educational technology, and a few from the trades areas. After the team determined which teachers were from TED, a computer generated random process – as required by the project's research design – selected 16 teachers to participate. In early April, letters were sent to those selected, congratulating them on joining the project and providing them information regarding their roles and responsibilities. The teachers' demographics show approximately 56% coming from Virginia, 19% from North Carolina, 19% from Illinois, and 6 % from Ohio. Of these teachers, 69% are male and 31% female. Eight are middle school teachers, eight teach at the high school level.

In September 2012, once the initial pilot test participants had been selected, a unique user access was created for each of the 16 teachers. All 16 teachers confirmed receipt of the login information and conducted an initial system entry at the request of the project team. Once successful entry had been documented through the system, teachers were then given the task of completing all 17 LOs within the four units, pretest administration prior to implementing the Engineering by Design unit of instruction, posttest administration after implementing the Engineering by Design unit of instruction, and submission of six NBPTS-based entries pertaining to assessment, instruction, management, and self-reflection. The intent of the system was to create a flexible means for in-service professional development, so the implementation purposefully avoided stating incremental deadlines of completion of the LOs and units. However, an end date for data collection was identified for late April 2013. Again, at the time of this proceeding the pilot teachers had access to the T2I2 system for approximately three months.

Data and Analysis

Teacher user data has been and continues to be collected concerning unit assessment quiz outcomes, attempts of a unit, and teacher time on task (see Table 2). User data provides direct feedback addressing project team concerns of access, progress, and success on the part of the pilot teacher. To date, of the pilot teachers completing quizzes all satisfactorily reached attainment of the four unit constructs. Quiz attempts have ranged on average from 3.15 to 4.5 dependent on T2I2 unit. Time on task information has just begun to be collected and only has a single participant access of a single unit and is not indicative of the broader base of pilot participants.

Table 2. T2I2 unit teacher user data

Units	Mean Quiz Scores	Average Number of Attempts	Time on Task (seconds)
Assessment of Student Learning	94.50	4.50	327.6
Demonstration Lesson	100.00	3.83	NA
Fostering Teamwork	98.46	3.15	NA
Documented Accomplishments	97.78	3.22	NA

Additionally, access data were collected, and still continues to be, pertaining to overall unit views, views per day, and average time spent on a unit per teacher (see Table 3). The system access data has unit views that range from 205 to 1001, average views per day that range from less than 1 to 3.65, and average time on units ranging from less than 3 minutes to 6 minutes.

Table 3. T2I2 system teacher access data

Units	Total Unit Views	Average Unique Unit Views per Day	Average Time Spent on Unit (seconds)
Assessment of Student Learning	1001	3.65	203.4
Demonstration Lesson	395	1.59	170.2
Fostering Teamwork	376	2.00	359.4
Documented Accomplishments	205	0.95	176.2

Conclusions

The intent of this proceeding was to report work-in-progress system data specific to professional development delivery of an initial pilot teacher group of grades 6-12 technology, engineering, and design education practitioners. Pilot teachers actively viewing/completing units and LO assessments are developing a satisfactory level of competency as evidenced by mean unit outcome requiring relatively low frequency pertaining to attempts. It appears that initial orientation to the LO and unit structure resulted in additional access to the first unit (Assessment of Student Learning) above the three other subsequent units. Unit 3 Fostering Teamwork appears to require supplemental time in comparison to the other three units. This is likely to be a direct result of six LOs composing a single unit in relation to the five LOs in Unit 1 Assessment of Student Learning, the three LOS that make-up Unit 2 Demonstration Lesson, and the three LOs that constitutes Unit 4 Documented Accomplishments.

The future of this project entails full data collection gauging how teachers use knowledge of their students to design assessments, how assessment relates to course learning goals and how problem-solving can be incorporated into assessment design. In addition to assessment, instructional development that further fosters teamwork of students while establishing a safe and encouraging learning environment is a desired participant outcome. Finally, activities that pilot teachers have participated in and specific accomplishments that have led to a positive impact on student learning are documented. The anticipated end product of this initiative is an evidence informed system that broadens technology, engineering, and design teachers instructional abilities and skillsets to promote STEM literacy for 6-12 students.

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